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INSTITUTE REPORT NO. 56

PHYSIOLOGICAL, PSYCHOLOGICAL, AND SYMPTOMATIC FACTORS AFFECTING PROLONGED PHYSICAL PERFORMANCE

DAVID A. STAMPER, M.A.

MILITARY STRESS DIVISION
DEPARTMENT OF BIOMEDICAL STRESS

JULY 1978

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14

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: LAIR-56
2. GOVT ACCESSION NO.: ✓
3. RECIPIENT'S CATALOG NUMBER: 9

4. TITLE (and Subtitle): 6 PHYSIOLOGICAL, PSYCHOLOGICAL, AND SYMPTOMATIC FACTORS AFFECTING PROLONGED PHYSICAL PERFORMANCE.

5. TYPE OF REPORT & PERIOD COVERED: Final rept. September 1975 - January 1976

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): 10 David A. Stamper ~~M.A.~~

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Military Stress Division, SGRD-ULB-MS, Department of Biomedical Stress, Letterman Army Institute of Research, Presidio of San Francisco

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 16 3M161102BS02, 065

11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Medical Research and Development Command, Fort Detrick, Frederick, Maryland 21701

12. REPORT DATE: 11 July 1978

13. NUMBER OF PAGES: 62

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 61 p.

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Personality, Tests, Assessment, Exertion, Fatigue, Sports, Work, Heart Rate, Humans, Male, Ventilation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During long-term physical performance tasks individuals rely on feedback mechanisms which enable them to adjust the work load level. This feedback process is hypothesized 1) to be important when successful completion of the task and/or time limitations are imposed on the individual, 2) to reflect ongoing physiological changes, and 3) to be affected by an individual's personality which can modify the perception of sensory information.

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Evaluation of the results from 13 of 14 male volunteers (18 to 27 years old, 56.7 to 85.7 kg) who rode a bicycle at approximately 65% V_{O_2} Max showed that Leg Fatigue and General Fatigue subscale scores from the Physical Activity Questionnaire (PAQ) increased significantly from three minutes to end-of-ride. Significant relationships were also found between these subscales and electromyographic recordings (EMG), and between these subscales and cardiopulmonary variables. The same three minute to end-of-ride comparison made for the Cardiopulmonary subscale indicated that the subjects were not uniformly affected by the work. For this subscale, the scores for the short riders (<16 minutes) and long riders (>32 minutes) increased significantly, but scores for intermediate riders (16-32 minutes) did not. Heart rate data for these groups also showed this pattern across the groups. The Motivation subscale showed essentially no change throughout the ride. This finding was proposed to be related to the the instructions for the ride which were not intended to be highly motivating.

Results of a series of multiple regression analyses of the physiological data obtained from 12-minutes into the ride indicated that 1) scores for the physiological data that were based on the percent of their respective 3-minute values could be used to predict ride duration ($R = 0.94$) better than the raw score form ($R = 0.55$); 2) General Fatigue and Cardiopulmonary subscales in combination could be used to predict ride duration while Leg Fatigue and Motivation added little to the regression equations; and 3) the PAQ subscale General Fatigue with three physiological variables in a combined analysis could be used to predict total ride duration at an extremely high confidence level ($R = 0.99$, $P < 0.001$). Apparently, some additional variability related to feelings of general fatigue experienced while performing this work task has yet to be specified.

Only one subscale from the three personality tests, i.e., the Disinhibition subscale of the Sensation Seeking Scale (SSS-DIS), was related to total ride time. However, contrary to the inhibition/satiation model proposed, the relationship was negative. Specifically, individuals that performed best on this physical endurance task were those who tended to show the lowest scores (the more inhibited persons). This suggests that the original model that has as its basis the inhibition/satiation hypothesis may not be sufficient. Perhaps specific psychosocial, work intensity, and stimulus intensity factors must also be considered.

ABSTRACT

During long-term physical performance tasks individuals rely on feedback mechanisms which enable them to adjust the work load level. This feedback process is hypothesized: (1) to be important when successful completion of the task and/or time limitations are imposed on the individual; (2) to reflect on-going physiological changes; and (3) to be affected by an individual's personality which can modify the perception of sensory information.

Evaluation of the results from 13 of 14 male volunteers (18 to 27 years old, 56.7 to 85.7 kg) who rode a bicycle at approximately 65% $\dot{V}O_2$ Max showed that Leg Fatigue and General Fatigue subscale scores from the Physical Activity Questionnaire (PAQ) increased significantly from three minutes to end-of-ride. Significant relationships were also found between these subscales and electromyographic recordings, and between these subscales and cardiopulmonary variables. The same three minute to end-of-ride comparison made for the Cardiopulmonary subscale indicated that the subjects were not uniformly affected by the work. For this subscale, the scores for the short riders (<16 minutes) and long riders (>32 minutes) increased significantly, but scores for intermediate riders (16-32 minutes) did not. Heart rate data for these groups also showed this pattern across the groups. The Motivation subscale showed essentially no change throughout the ride. This finding was proposed to be related to the instructions for the ride which were not intended to be highly motivating.

Results of a series of multiple regression analyses of the physiological data obtained from 12 minutes into the ride indicated that 1) scores for the physiological data that were based on the percent of their respective 3-minute values could be used to predict ride duration ($R = 0.94$) better than the raw score form ($R = 0.55$), 2) General Fatigue and Cardiopulmonary subscales in combination could be used to predict ride duration while Leg Fatigue and Motivation added little to the regression equations, and 3) the PAQ subscale General Fatigue with three physiological variables in a combined analysis could be used to predict total ride duration at an extremely high confidence level ($R = 0.99$, $P < 0.001$). Apparently, some additional variability related to feelings of general fatigue experienced while performing this work task has yet to be specified.

Only one subscale from the three personality tests, i.e., the Disinhibition subscale of the Sensation Seeking Scale (SSS-DIS), was related to total ride time. However, contrary to the inhibition/satiation model proposed, the relationship was negative. Specifically, individuals that performed best on this physical endurance task were those who tended to show the lowest scores (the more inhibited persons). This suggests that the original model that has as its basis the inhibition/satiation hypothesis may not be sufficient. Perhaps specific psychosocial, work intensity, and stimulus intensity factors must also be considered.

PREFACE

This research was performed as part of a long-term training program sponsored by the Letterman Army Institute of Research and the Department of the Army. This project was submitted to the Faculty of the Graduate School of the University of Colorado in partial fulfillment of the requirements for the degree of Master of Arts from the Department of Environmental, Population, and Organismic Biology.

I would like to thank Dr. Andree Lloyd and Dr. Bruce Leibrecht for their helpful criticisms of the manuscript and for editorial assistance of Ms. Lottie Applewhite and Mrs. Barbara Beagle. The administrative problems encountered during this entire period were minimized due to the efforts of COL J. E. Canham, COL C. T. Hino, and Dr. J. P. Hannon, to whom I am greatly indebted. I would also like to express my appreciation to my committee members, Dr. Philip Weiser, Dr. Arthur Dickinson, Dr. David Chiszar, and Dr. Paul Winston for their invaluable direction, understanding, and support throughout this entire project. A special note of appreciation is given to Dr. Dickinson, who provided the facilities of the Human Performance Laboratory of the Physical Education Department, his time, and his technical assistance that went far beyond any reasonable expectation. Also, to Mr. Michael Phillips for his relentless dedication to this project I shall always be grateful. I would also like to thank Dr. Robert Grover of the Cardio-Vascular Pulmonary Laboratory at the University of Colorado Medical School for analysis of the standard gases used for calibration. The MAX computer program used for the analysis of the cardiopulmonary data was written by Mr. James Morrow for the Human Performance Laboratory of the Physical Education Department at the University of Colorado. The Sensation Seeking Scale (Form IV) was most thoughtfully provided by Dr. Marvin Zuckerman (Psychology Department, University of Delaware). Finally, to Karen, Corri, John, Victoria, and Maggie, thank you for your patience and understanding during this period.

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INTRODUCTION

The subjective experience of fatigue has been proposed to be an important factor limiting sustained physical activity (1,2). During such work, the level of energy expenditure and/or the length of time individuals will continue to perform must necessarily involve an ongoing evaluation of the subjective symptomatology that is associated with the task. A basic assumption implied in this rationale is that the symptomatology changes reflect changes in the physiological states of individuals. Hence, the ongoing subjective experience provides the individual with information about physiological functioning at a given time.

Physiological changes which have been proposed to be among the major contributing factors limiting sustained physical activity have included depletion of muscle glycogen (3), liver glycogen (4), and muscle acidosis (5,6). While considerable data are available for most of these factors, there still remain individual differences in the duration of physical performance tasks which cannot be explained solely on the basis of physiological variables. One possible explanation hypothesized for these individual differences involves the inhibition/satiation phenomenon which affects the processing of somatosensory information (7). Several investigators (8-11) have shown that individual performance differences can be related to personality types that are based on the inhibition/satiation phenomenon.

Noticeably lacking in the area of factors affecting prolonged physical performance is a model which attempts to show the possible relationships among such physiological and psychological variables as those just mentioned. Such a model is now presented in Appendix A,

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1. Kinsman, R.A. et al. Ergonomics 16:211, 1973
2. Weiser, P.C. et al. Med Sci Sports 5:79, 1973
3. Hultman, E. Scand J Clin Lab Invest 19(Suppl 94):1, 1967
4. Issekutz, B. et al. J Appl Physiol 29:691, 1970
5. Hermansen, L. and J-B. Osnes. J Appl Physiol 32:304, 1972
6. Osnes, J-B. and L. Hermansen. J Appl Physiol 32:59, 1972
7. Lynn, R. and H.J. Eysenck. Percept Mot Skills 12:161, 1961
8. Witkin, H.A. et al. Personality Through Perception: An Experiment and Clinical Study. 1954
9. Farley, F. and S.V. Farley. J Consult Psychol 31:215, 1967
10. Eysenck, H.J. The Biological Basis of Personality. 1967
11. Petrie, A. Individuality in Pain and Suffering. 1967

Figure 1. Briefly, when the individual decides to initiate or continue the work (A), a modification of effort (B) is compared to some work reference (C). The task will begin or continue provided that a physical limitation (D) is not present which would cause the individual to stop (E). As the task continues, physiological responses (F) occur which give rise to sensory cues (G) whose pathways extend to specific and non-specific areas of the thalamus and limbic system, provided that the individual is attending (H) in some selective manner to the physiological responses. These cues arrive at the somatosensory cortex which are intrepreted by the individual and given labels in the form of symptoms (I). The symptoms are evaluated by the individual, and the decision to stop or to continue is then made. Personality (J) and task requirements (K) serve to modify the intensity of the physiological responses, sensory cues, and/or symptomatology at each level. Feedback loops are included to account for the effects of training and pathology (L). Specific symptomatic manifestations of physiological events that are related to bicycle ergometer work are also shown on Figure 1.

Subjects

The subjects were 14 male students ranging from 18 to 27 years of age and weight from 56.7 to 85.7 kg of body weight (Appendix B, Table 1). The 14 volunteers were selected from physical education classes at the University of Colorado. The educational majors of the volunteers included political science, art, and basic science as well as physical education. For participation in the study the subjects received no monetary reward but were told that they would receive information regarding their present state of physical fitness.

General Procedure

Following a briefing in their classrooms the volunteers were sent to the student health center for physical examinations to determine if they had any physical conditions which would preclude safe participation in strenuous physical exercise. Prior to beginning the study all participants read and signed an informed consent statement (Appendix C), in which they acknowledged that the general intent of the research, the procedures, and the possible health hazards had been explained to them.

On the morning of each test session the subjects were told to eat only a light breakfast (e.g., toast and juice). They arrived at the laboratory between 0700 and 1200 hours for each test session. The schedule of the rides is presented in Table II. Each ride was separated by a minimum seven-day period to reduce the likelihood of any practice effects. The maximum oxygen uptake procedure ($\dot{V}_{O_2}$ Max) that was performed in Session 2 for subjects 1-9 was combined with the familiarization ride in Session 1 for subjects 10-14. This change was made because subjects 1-9 were asked to return for an additional ride at 85% of $\dot{V}_{O_2}$ Max that included a five-minute warm-up. The results of the 85% $\dot{V}_{O_2}$ Max ride with the warm-up will not be discussed as part of the thesis.

With this change, subjects 10-14 were told, as were subjects 1-9, that the study would require three rides, and the number of practice trials where the Physical Activity Questionnaire (PAQ) (Appendix D) was given remained the same. The additional amount of time that subjects 1-9 spent on the bicycle ergometer (three five-minute intervals) should not have offered any lasting practice effects. Supportive evidence for this contention is offered by the ride durations for the two groups on the 65% $\dot{V}_{O_2}$ Max endurance ride which were ($\bar{X}$ Range) 34.9 min, 9.9-65.5 min; and 35.2 min, 12.3-68.9 min for subjects 1-9 and 10-14 respectively. Upon completion of both endurance rides, each subject was given a copy of the thesis proposal, and questions regarding the entire study were answered at that time.

The intent of this thesis will be to test those aspects of the model (Figure 1) which propose that symptomatology changes experienced while riding a bicycle ergometer are related to physiological alterations (i.e., F with I) and that personality differences (J) affect the duration of the task. The study is reported in two parts: (1) relationships between symptomatology reports and physiological changes, and (2) personality and ride duration. The results show that differences in ride duration can be predicted from physiological and symptomatic factors and that differences in ride duration are related to personality factors.

RELATIONSHIPS BETWEEN SYMPTOMATOLOGY REPORTS AND PHYSIOLOGICAL CHANGES

Selection of variables to test for relationships between physiological events and subjective symptomatology should consider the amount of information that is known about each area. To determine an accurate figure would be difficult; however, it can be reasonably assumed that considerably more information is available regarding physiological responses. This suggests that the approach which begins with the selection of symptomatology reports that may be related to physiological events would have considerable merit. Recently, unidimensional scales of effort or fatigue (12,13) have become popular. However, such scaling techniques tend to ignore the essential complexity of the subjective work experience and thereby provide only a partial description. The Physical Activity Questionnaire (PAQ) (1,2) was introduced to overcome these limitations.

The PAQ is a self-report inventory that was developed to assess the subjective symptomatology experienced during work on a bicycle ergometer. Key-cluster analysis of a large group of items yielded

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12. Borg, G. Physical Performance and Perceived Exertion. 1962
13. Pearson, R.G. and G.E. Byars. USAF School of Aviation Medicine. Report No. 55-115. 1956

select groups (clusters) of symptoms for which subscale scores could be obtained by summing the raw score ratings of items that comprise each cluster. The fundamental concept which entails the specification of general and unique factors was used by Spearman (14) who applied this concept to his early work on intelligence. Weiser et al. (2) and Kinsman et al. (1) reported that the PAQ factor structure contained two general clusters (General Fatigue and Motivation) and two specific clusters (Leg Fatigue and Cardiopulmonary Distress). While the general factors may account for a substantial amount of variability in the score space, the specific factors allow for the evaluation of similar but in some unique way different test situations. It was anticipated that the subscales would provide a more complete description of the subjective experience of prolonged work on the bicycle ergometer and that more accurate predictions (of such factors as ride duration) could be made from the subscale scores than from a single PAQ total score.

When designing experiments involving human subjects, the procedural requirements are often weighed against the anticipated results. For example, the studies in Hultman (3), Issekutz et al. (4), Hermansen and Osnes (5) require considerable technical and financial support that is not always readily available. However, noninvasive procedures such as electrocardiographic (ECG) recording (15), surface electromyographic (EMG) assessment (16), and respiratory function (17) can be performed with relative ease and reflect important changes that occur during physical work. From such monitoring, information regarding cardiopulmonary and fusimotor system changes can be determined.

This chapter will provide data which may establish relationships between symptomatology reports and physiological events. The hypothesis will be evaluated by using four subscales of the PAQ, which should provide adequate information on subjective symptomatology experienced during the work task. While the General Fatigue and Motivation subscales will be administered, heart rate (HR), volume of gas expired ($\dot{V}_E$ BTPS), respiratory rate (RR), tidal volume (V_T), respiratory quotient (RQ), oxygen uptake ($\dot{V}_{O_2}$), estimated cardiac output (CO), and estimated stroke volume (SV) will be recorded as variables to be specifically related to the cardiopulmonary subscale. EMG recordings that will be related to the Leg Fatigue subscale will include peak-to-peak amplitude and duration of the signals from the quadriceps femoris (vastus lateralis) and gastrocnemius muscles.

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14. Spearman, C. Am J Psychol 15:268, 1904
15. Weiser, P.C. et al. Fed Proc (Abstract) 30:372, 1971
16. Lloyd, A.J. et al. Ergonomics 13:685, 1970
17. Gleser, M.A. and J.A. Vogel. J Appl Physiol 31:735, 1971

METHODS

Apparatus

Figure 2 presents a diagram which depicts the physical arrangement of the work situations. The work was performed on an electrically braked bicycle ergometer (Quinton). Expired air was collected using open circuit spirometry with the subject wearing a face mask (Monahan) which led to a dry gas meter (Parkinson-Cowan), and finally into meteorological neoprene bags. The dry gas meter was checked for calibration three times during the course of the experiment (error <2 L/100 L). The dry gas meter was interfaced with a chart recorder (Physiograph, Narco-Bio) to provide a permanent record of volume ($\dot{V}_E$) and respiratory rate (RR). The expired air was analyzed for O_2 and CO_2 (Godart Rapox and Capnograph analyzers, respectively), and the analyzers were checked for calibration before and after each ride with O_2 and CO_2 gases which had been analyzed by using the Scholander technique (18). Heart rate was determined from an electrocardiogram recording that was obtained with a telemetry unit (Narco) attached to the subject. Intermittent recording of the ECG was maintained.

The sixteen PAQ items (Appendix D) were shown to the subjects on a screen placed directly in front of the bicycle ergometer. A slide projector presented each item individually and its 5-point Likert-type rating scale. Selection of the items was based on the results of work by Weiser et al. (2) and another report in preparation. The number of items within each scale was restricted to four to minimize the time needed to complete the questionnaire. Four separate sequences of the sixteen items (four subscales with four items each) were arranged in the circular slide tray with each sequence separated by black slides. To reduce the likelihood of establishing a response set, the items were randomly presented within each sequence with eight items scaled from absent to severe and the remaining items from severe to absent. Furthermore, the severe-to-absent and absent-to-severe scaling of each item occurred twice in the four sequences. The PAQ reports were obtained by asking the subject to hold up one to five fingers to indicate the number that corresponded to the adjective for each item that described how he felt at that moment. The responses were recorded on a standard computer card form sheet. The approximate time required to complete the PAQ was one minute 30 seconds to one minute 45 seconds.

The EMG peak-to-peak amplitude and duration measures were obtained by measuring each trace on the strip chart records with a plastic ruler and a magnifying glass. Each score represented the mean value of ten bursts that were taken from the period during which the other physiological measurements were obtained.

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18. Consolazio, C.F. et al. Physiological Measurements of Metabolic Functions in Man. 1963, p 72

Procedure

Table II of Appendix B shows the sequence of the test sessions. During the first session the subjects read and signed a subject informed consent statement wherein they acknowledged that the general intent of the study had been explained, along with the possible risks involved. Following this the three personality questionnaires were administered (see section titled, Personality and Ride Duration), and for familiarization purposes, the PAQ was completed three times while riding the bicycle ergometer. As noted in the General Procedure section, this ride consisted of three submaximal 5-minute rides for subjects 1-9, and the $\dot{V}_{O_2}$ Max ride for subjects 10-14.

Determination of $\dot{V}_{O_2}$ Max values were made according to a continuously graded cycling protocol similar to that described by McArdle et al. (19). An rpm meter was mounted on the handle bars of the bicycle ergometer. Briefly, each subject began pedaling at approximately 60 rpm and at a work load which insured a minimal 5-minute work period prior to the beginning of the gas collection. Every two minutes the work load was increased 200 kpm until the subject could no longer continue. As the subject's heart rate approached 170 bpm, he was repeatedly asked how much longer he could continue. Gas was collected when it was felt that the subject had approximately three minutes remaining (i.e., three one-minute samples). The 65% and 85% work loads were then estimated by using a graphic representation of work load against $\dot{V}_{O_2}$ found in Table A-3 from Åstrand and Rodahl (20). Therefore, according to this work protocol the intended work load of either 65% or 85% $\dot{V}_{O_2}$ Max was to be reached at five minutes into the ride. This does not infer that these respective work loads were maintained throughout the ride. Only one occasion was this estimate observed to be totally inaccurate, and the subject was told to stop and was asked to return on another occasion when the work load was reduced to the appropriate level. The endurance rides were counterbalanced with half of the subjects receiving the 65% $\dot{V}_{O_2}$ Max first and the remaining subjects receiving 85% $\dot{V}_{O_2}$ Max first.

Immediately preceding the first endurance ride, the motor point of the quadriceps femoris (vastus lateralis) muscle was found by determining subjectively the location at which a low voltage muscle stimulator elicited a maximum contraction. The same procedure was followed for the gastrocnemius muscle, and both points were marked with a 70% solution of aqueous $AgNO_3$ and fixed with a film developing fixer. This procedure allowed for rapid placement of the electrodes during the second ride and worked well in most cases. However, the subjects were asked to return and have the spots re-marked if they began to fade. Two EMG bi-polar surface electrodes (silver-silver chloride) which had been mounted on a

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19. McArdle, W.D. et al. Med Sci Sports 5:156, 1973
20. Åstrand, P. and K. Rodahl. Textbook of Work Physiology. 1970, p 619

wooden support were affixed over the motor point areas as close together as possible to attempt to reduce movement artifacts. The ground electrode was placed on the posterior surface area above the ulna near the styloid process. The ECG surface electrodes were placed as nearly as possible to approximate the V_4 position for ECG recording. The subject was then placed on the bicycle ergometer where the face mask was positioned, and interfacing connections were made with the recorder. Prior to and subsequent to each ride, maximum contractions of the vastus lateralis and gastrocnemius muscles were performed. The recovery pattern, i.e., the amount of decrement or increment relative to the pre-ride values, showed no consistent relationship to the degree of the decrement that was found during the ride.

To begin the experiment the subject was told to begin pedaling at 60 rpm and "to keep pedaling at 60 rpm until you cannot maintain that rate any longer." The subjects were periodically asked how they were doing, but to provide a similar external motivational environment for each subject, no further encouragement was offered. Recording of the physiological data occurred during the one-minute interval prior to the following indicated sample times, while the symptomatology reports were obtained in the period immediately afterwards. This was done to reduce the likelihood of the PAQ procedure affecting physiological measures, e.g., respiratory rate. The scheduled recording of the physiological and PAQ data occurred at 3, 6, 9, 12, 20, 30, 40, etc, minutes until the subject indicated that he was going to stop. When the subject wanted to stop he would hold up two fingers, indicating that he would ride for two additional minutes. The PAQ was then begun, and one minute later the physiological measurements were taken for a one-minute period. The work load was then immediately reduced to 200 kpm, the respiratory mask was removed, and the subject was told to keep pedaling at a rate that felt comfortable to him. ECG and blood pressure were monitored during the subsequent 4-5 minute cooling down period.

Test Scores and Statistics

The cardiopulmonary measurements, excluding HR, V_T, and RR were calculated using standard Haldane computational procedures (21) and Rushmer tables that were contained in the program MAX (see acknowledgement in Preface). The HR and RR values were obtained from the chart recordings during the one-minute periods noted above. The V_T values were then calculated according to the following equation: $V_T = \dot{V}_E/RR$. Since the raw score form of certain of the physiological measures will vary according to each individual's capacity (e.g., $\dot{V}_E$), a score that was based on the percent of change relative to its 3-minute value was also calculated and included in the correlational analysis. The 3-minute value was used instead of the baseline score since it was speculated that

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21. Haldane, J.S. and J.G. Priestley. Respiration. 1935

anticipation of the exercise bout would likely elevate the baseline values of several of the cardiopulmonary measurements. These calculations were performed for $\dot{V}_E$, $\dot{V}_{O_2}$, RQ, CO, SV, HR, $\dot{V}_R$, and V_T. References to these values will include a "P" preceding the symbol (e.g., PRQ). One exception is P$\dot{V}_{O_2}$ Max, which represents the percent of $\dot{V}_{O_2}$ Max based upon the subjects' $\dot{V}_{O_2}$ Max work load determination ride. This procedure has the value of equating subjects based upon their individual capacities.

Each of the PAQ subscale scores was computed by summing the raw data scores for the items that comprised their respective subscales. For a more complete description of the procedure, see Kinsman et al. (1) and Weiser et al. (2). The Pearson product-moment correlations and the multiple step-wise regression analyses, that were used to determine relationships between the PAQ subscales and physiological data and to predict ride duration by using PAQ subscale scores and physiological data respectively, were accomplished by using the Statistical Package for the Social Sciences system (SPSS). The data for the simple correlational analysis between the PAQ subscales and physiological measures were comprised of all of the observations for all of the subjects throughout their respective rides (total = 86). This was done because it was viewed that at each point in time the subscales should reflect the current physiological status of the subject. While the shortcomings of this procedure are recognized (e.g., an individual contributing some unique source of variation), the additional data obtained for the Leg Fatigue and EMG correlations for which there were missing data (see results) offered additional merit for this approach. To determine the significant changes from 3-minute to end-of-ride for the three groups of subjects (see results), t-tests for related samples were used. The 0.05 confidence level was used in all cases for determining significance. When missing data occurred, the missing data options contained in the programs were used if appropriate. With the exception of the EMG recordings, missing data occurred only at three points within the entire study.

The 85% $\dot{V}_{O_2}$ Max ride data were intended to provide validity for PAQ subscale changes by showing higher subscale scores relative to the 65% $\dot{V}_{O_2}$ Max ride. However, because of short ride times for several subjects (5 of the 14 did not reach the 9-minute collection period) and the relatively large number of missing EMG data points (five complete sets and several others which were incomplete), the 85% $\dot{V}_{O_2}$ Max ride was dropped from further consideration in this section. The results of only 13 subjects, the ones who completed the 65% $\dot{V}_{O_2}$ Max ride will be discussed in detail in the subsequent section.

In the subsequent analysis and discussion of these data, subjects were separated into three groups. The subjects who rode 32 minutes or less were placed into one of two groups: Group 1 (N = 4) consisted of those who rode less than 16 minutes, and Group 2 (N = 4) consisted of those who rode between 16 and 32 minutes. The remaining five subjects (Group 3) were clearly distinct from groups 1 and 2 in that all of their ride times exceeded 54 minutes. With this categorization additional information

could be obtained by comparing the results of long, intermediate, and short riders. The presentation of the PAQ subscale and physiological changes of the three groups are graphically depicted in Figures 3 to 8.

RESULTS

The overall work characteristics for the 13 subjects are summarized in Table I. Means and standard deviations ($\bar{X} \pm SD$) for ride duration and percent of $\dot{V}_{O_2}$ Max at which subjects rode were 35.01 ± 21.98 and 66% ± 6% respectively. Following the calculation of $\dot{V}_{O_2}$ values for subject 5 it was determined that at five minutes his rides were being performed at 79% and 99% $\dot{V}_{O_2}$ Max, instead of 65% and 85% respectively. Therefore, the decision was made to include his 79% $\dot{V}_{O_2}$ Max as part of the 85% $\dot{V}_{O_2}$ Max ride data of other subjects and to drop the 99% $\dot{V}_{O_2}$ Max from further consideration. Such a decision was considered justified since the instructions for both rides were the same.

Leg Fatigue and Electromyographic Responses

Time course changes on the Leg Fatigue subscale for each of the three groups are presented in Figure 3. Because of the differences in ride duration, the mean value for the final data point is based on their end-of-ride scores. Inspection of this figure indicates that by 3 minutes the scores of the short riders were slightly elevated and by end-of-ride the scores had reached a higher level than did the scores for either group 2 or 3. The results of the t-test for related samples for the 3 minute to end-of-ride changes have been summarized in Table III. The 3-minute to end-of-ride changes shown in Figure 3 were all found to be significant at the $P < 0.05$ level and beyond.

To determine the significant relationships between the Leg Fatigue subscale and the pre-selection physiological variables (i.e., amplitude and duration of the vastus lateralis and gastrocnemius EMG signals), Pearson product-moment correlations were computed for all data entries. The results of these analyses and those computed between the other PAQ subscales and their pre-selected physiological measures are summarized in Table IV. Because of technical difficulties, which were probably attributable to movement artifacts, the EMG tracings of several subjects were uninterpretable. By the end-of-ride, subjects for which there existed complete data were: Group 1, N = 3; Group 2, N = 3; and Group 3, N = 2. The duration of the EMG signals from the vastus lateralis and gastrocnemius were significantly related to Leg Fatigue scores (Table IV). Therefore, if the EMG signals were graphically presented, a similar pattern of scores to those depicted in Figure 3 should be apparent. Figure 4 shows the changes in the duration of the gastrocnemius EMG signal. Across time a general decrease is evident for all groups: however, Groups 1 and 2 show a substantial recovery during the final minute of their rides. The t-test comparisons of these 3-minute to end-of-ride changes (Table III) indicate that Group 1 scores did not decrease significantly, but that Groups 2 and 3 did.

Cardiopulmonary Subscale Changes and Measures of Cardiopulmonary Function

Graphic representation of the mean Cardiopulmonary subscale scores for each of the three groups of subjects are presented in Figure 5. Differences in the rate of increase among the three groups of subjects can be seen. Group 1 showed substantial increases from 3-minute to end-of-ride; Groups 2 and 3 had only minimally elevated scores. The t-test comparisons of these 3-minute to end-of-ride changes revealed that the scores for both Groups 1 and 3 were significantly increased, but not for Group 2. A non-significant increase from 3-minute to end-of-ride does not necessarily infer that the same result would be true if pre-ride scores were compared to the end-of-ride ratings. Inspection of Table IV, which lists the correlations between the Cardiopulmonary subscale and the raw score form of the ten pre-selected cardiopulmonary measures, indicates that heart rate (HR) was the only cardiopulmonary function significantly related to Cardiopulmonary subscale scores. The additional nine correlation coefficients between Cardiopulmonary subscale scores and scores based on percent of 3-minute values showed that $P\dot{V}_{O_2}$ and PV_T were significantly related. In this case it would appear that the raw score form of heart rate was superior to the PHR calculated scores. These findings also indicate that an increase in the report of cardiopulmonary sensations should be associated with a change in HR, $P\dot{V}_{O_2}$, and PV_T. Therefore, as with the duration of the gastrocnemius EMG bursts, the HR data were selected to determine if similar patterns of changes for these three groups of subjects could be found. These changes are presented in Figure 6. Supportive evidence for the subscale changes as reflecting underlying physiological events is apparent. While all three groups showed significant 3-minute to end-of-ride increases (Table III), Group 2 heart rates increased from 3 to 6 minutes, but remained relatively unchanged thereafter. Thus, the non-significant increase of the Cardiopulmonary subscale by Group 2 noted earlier does appear to have some support based on the inspection of these heart rate changes.

General Fatigue and Related Physiological Responses

The mean General Fatigue subscale scores for the three groups of subjects across time are graphically presented in Figure 7. Comparison of the changes among the groups indicates that the responses of Groups 1 and 2 were similar; they reflected a relatively rapid and almost linear increase from 3-minute to end-of-ride. While the responses of subjects in Group 3 were also approximating a linear increase, the rate was more gradual. The 3-minute to end-of-ride t-test comparisons were all significant beyond the 0.05 confidence level. Since the state of general fatigue was hypothesized to have as its physiological basis input from several systems, correlation coefficients were computed between General Fatigue subscale scores and all of the physiological measurements obtained. The results of these computations are presented in Table IV. Of the 23 coefficients computed, 12 were significant. Such a finding suggests that determinants of General Fatigue reports arise from a variety of sensory information. Also in this analysis when the scores for cardiopulmonary function represent values based on percent of a 3-minute score

were used, a substantial improvement in the magnitude of the correlation coefficients occurred. A figure which represents changes for one of the physiological variables that was found to be related to General Fatigue has not been included at this time. It is this author's opinion that sufficient emphasis on group differences across time included in the presentation of the Leg Fatigue and Cardiopulmonary subscales need not be demonstrated further. Table IV and Figure 7 provide additional information.

Motivation and Physiological Responses

The findings for the Motivation subscale are illustrated in Figure 8 for each of the three groups of subjects. Inspection of this figure indicates that the groups began at essentially the same level, and while the scores for Group 3 decreased from 3 to 9 minutes (i.e., reflecting an increased motivation level), their end-of-ride values were relatively unchanged. The t-tests for related samples computed between the 3-minute and end-of-ride scores (Table III) indicated that none of the end-of-ride scores increased significantly above the 3-minute level. The only suggestion of a change can be seen between the mean end-of-ride value and the mean value (circled) for that collection period by Groups 1 and 3. The relatively increased reports above the mean end-of-ride score of the remaining subjects during those specific points in time could indicate that these subjects did in fact experience a decreased level of motivation.

Prediction of Ride Duration

The purpose of the multiple step-wise regression analyses performed in this section was 1) to identify the physiological factors which account for the greatest amount of variability in ride duration, 2) to compare the results of that analysis with the PAQ subscales analysis, and 3) to show the relative importance of the subjective experience of fatigue by performing an analysis that includes the physiological factors and the PAQ reports. Because of the differences in the magnitude of the correlation coefficients that have been observed between the raw score form of the physiological data and values that were based on the percent of 3-minute values, a regression analysis was also performed for each form of the data. The data used for these analyses were obtained at 12 minutes into the ride. This period was selected based on PAQ results from an earlier report (2). Since there are only four PAQ subscales, the regression analysis performed on the physiological data was also limited to four steps. Additionally, no F or tolerance level was established for entry or deletion of the variables in the equation so that four steps would be completed to allow for comparison of the results for each analysis. The results of the four analyses are summarized in Table V.

The results of the analysis, wherein the raw score form of the physiological data was used, indicate that these variables were only able to account for minimal amounts of the variability in ride duration. The four variables, RR, HR, RQ, and $\dot{V}_{O_2}$, were only able to account for

30% of the variability in the dependent measure (R^2 x 100), and at no time during the step-wise procedure was the amount of variability determined to approach significance.

In the second analysis, with the use of the percent of 3-minute values, substantial improvement was found. First, the simple r for each of the four variables (i.e., PRQ, PV_T, $P\dot{V}_E$, and PSV) was in general higher; the multiple R was increased to 0.94 which accounts for 89% of the variability. Additionally, the significance level began beyond the 0.05 confidence level and continued to improve through the third step and decrease slightly with the inclusion of the fourth variable. These four variables show the highly desirable characteristics of being related to the dependent variable while being relatively unrelated to each other ($\bar{X}$ = 0.24). This can be seen by the substantial increase in the multiple R at each step.

The next regression analysis presented in Table V summarizes the results obtained when the four PAQ subscales were used. The results of this analysis are different from either of the two previous analyses in that while a substantial amount of variability in ride duration was accounted for, the more desirable characteristics exhibited by the variables in the second analysis are lacking. While all the subscales were, in general, moderately related to ride duration ($\bar{X}$ = -0.48 to -0.77), the relatively small increase in the multiple R after the first step (General Fatigue) indicated that the subscales must be substantially related to each other ($\bar{X}$ = 0.64). Such a finding is not totally unexpected because of the somewhat high intercorrelations that were noted by the developers of the subscale.

The final analysis presented in Table V is the result of the regression of the physiological variables (i.e., those based on the percent of 3-minute values) and PAQ subscale scores. The four variables selected in this analysis were General Fatigue, PRQ, PV_T, and PV_E. It can be observed that while the order of the first three variables remained the same in the analysis in which only the percent of 3-minute scores were used, General Fatigue was the most highly related variable to ride duration. Additionally, with the inclusion of General Fatigue a substantial improvement in the multiple R and F values were found.

COMMENT

To identify specifically certain physiological variables as the unique contributors to each of the subjective states reflected by the PAQ subscales could not be a realistic goal with only 14 participants. Rather, this study was intended to demonstrate the utility of such research and to assist in making logical decisions concerning future research of this nature. Also, it was not assumed that the physiological variables selected represented an exhaustive list of possible variables that could be related to the PAQ subscales.

A wide distribution of ride times despite the performance of work at the same relative percent of $\dot{V}_{O_2}$ Max was noted. Also the duration of these rides relative to those reported by other investigators e.g., Gleser and Vogel (17) merits further discussion. In this present study it was intended that the subjects should reach 65% of their $\dot{V}_{O_2}$ Max level by five minutes. This is three minutes sooner than Gleser and Vogel (17) required. However, direct comparison to their study is difficult because their rides were performed at 75% $\dot{V}_{O_2}$ Max. Additionally, the participants in the present study represented various levels of physical fitness while those in Gleser and Vogel's study (17) were generally in better condition. These factors and the personality variables that will be discussed in the next section may account for the differences in ride times among the subjects in this study and when compared with subjects in other reports.

The differences in the duration of the EMG burst may be reflecting changes in the pattern of motor unit activity that has been reported by several other investigators. Gollnick et al. (22), Costill et al. (23), and Saltin (24) have provided biochemical and histological evidence that as physical work continues at a work load similar to that used in the present study, there is a shift from a predominance of slow twitch fibers (low-threshold, aerobic, red muscle) to fast twitch (high-threshold, anaerobic, white fibers). The end spurt shown by Groups 1 and 2 in Figure 4 may reflect the recruitment of the fast twitch fibers. The lack of the recovery of the burst by Group 3 may indicate that the shift for this group occurred more gradually.

Cardiopulmonary subscale changes did not increase greatly from 3-minute to end-of-ride. It is not apparent whether this result indicates either that the items are not sensitive to changes in cardiopulmonary functioning, or that work performed at 65% $\dot{V}_{O_2}$ Max does not yield substantial increases in the perception of cardiopulmonary stress. If sufficient data had been available for the ride performed at 85% $\dot{V}_{O_2}$ Max, a comparison could have been made. The significant, but somewhat low, correlation found between the Cardiopulmonary subscale and HR (accounting for only 7% of the variability between the two variables) did receive some additional support. The observation that subscale scores for Group 2 did not increase signficantly from 3-minute to end-of-ride and that their heart rates remained essentially unchanged after 9 minutes can be viewed as an important consideration. A possible explanation of one mechanism that may be relevant to these results concerns the characteristics of rapidly adapting receptors. The neural firing patterns of these receptors to a constant stimulus is a return to a near pre-stimulus level following an initial burst, despite the continuation of the stimulus (25). Pressure

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22. Gollnick, P.D. et al. J Physiol 241:45, 1973
23. Costill, D.L. et al. Acta Physiol Scand 91:475, 1974
24. Saltin, B. Med Sci Sports 5:137, 1973
25. Grossman, S.P. Essentials of Physiological Psychology. 1973, p 29

and stretch receptors located in the respiratory muscles and surrounding area may accommodate despite the gradual increase in cardiopulmonary functioning (e.g., the heart rate increase of Group 3) that could be perceived by the individual as occurring at approximately the same intensity. The relationships between the Cardiopulmonary subscale and $P\dot{V}_{O_2}$ and PV_T are low, but nonetheless significant. Improved statistical results have been reported previously for variables that were adjusted for individual capacities. It was noted in two reports (26,27) respectively that the prediction of activity level from anaerobic threshold expressed as percent $\dot{V}_{O_2}$ Max and that the percent $\dot{V}_{O_2}$ Max-relative HR relationship was superior when compared to results where the raw score form of the data was used. Therefore, there may be some merit when comparing physiological changes among individuals to use values that are equated for individual differences.

The expectation that several physiological systems contribute to the feeling of General Fatigue received considerable support from the correlational analysis. Again, as noted with the Cardiopulmonary subscale, a substantial increase in the magnitude of the relationships was found when the percent of 3-minute values were used instead of the raw score form of the data. This finding also supports the statistical approach which accounts for differences in physiological capacities of individuals.

The motivation level of individuals performing physical work has been considered an important factor (28). The finding that motivation, as reflected by the PAQ Motivation subscale, was not an important factor during this exercise task presents a perplexing problem. Such results would indicate that either this scale is not measuring what it is purported to measure, or that the motivational level of these subjects was unaffected. First, while no attempt to validate this motivation subscale has been reported, the PAQ measurement characteristics (e.g., intercorrelations, reliabilities, and communality estimates of the items comprising this subscale) were reported to be among the highest of the subscales (1). Second, specific responses of the subjects to items in the Motivation subscale such as "Want to Perform Well" at 3 minutes were in the range of "Moderately" to "Considerably" (i.e., 3 to 4). By the end-of-ride, their responses had in general shifted downward to the range of "Slightly" to "Moderately" (i.e., 2 to 3). An important point to consider at this time is the instructions given to the individuals prior to each ride: "to keep pedaling at 60 rpm until you cannot maintain that rate any longer." In this study, instructions to the participants were purposely intended to be non-motivational because of the possibility of a differential effect that was not being evaluated. Therefore, it is suggested that the desired intent of the instructions

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26. Londeree, B.R. and S.A. Ames. Europ J Appl Physiol 34:269, 1975
27. Londeree, B.R. and S.A. Ames. Med Sci Sports 8:122, 1976
28. Morgan, W.R. Med Sci Sports 5:97, 1973

were effective, and apparently the initial motivation level did not affect performance. Additionally, this result suggests that evaluation of the more stable personality factors (discussed in the next section) which affect ride duration can be considered to be relatively independent of the more transient motivational changes.

Linear relationships between a unidimensional rating of perceived effort (RPE) and heart rate have been previously reported (12, 29-31). Subsequent work by Noble et al. (32) described the results of an attempt to predict RPE by using multiple regression techniques that included several of the same physiological measures used in the present study. Analysis of these data at 5 minutes showed that HR, RR, RQ, $\dot{V}O_2$, and $\dot{V}_E$ were included in the first five steps. These results compare favorably with those of the present analysis used to predict ride duration in which HR, RR, RQ, and $\dot{V}_E$ were also included, but not in the same order. A shortcoming, acknowledged by Noble et al. (32), was the use of only six subjects with eight independent variables. While F levels were not preset, as in the present study, the F values and significance levels were also not reported. Therefore, direct comparison of the two studies is difficult. However, the multiple R of 0.77, that was reported after four steps in which six subjects participated, does not represent strong support for further interpretation of the data.

The improvement in the prediction of ride duration, by using the percent of 3-minute values for the physiological data, was not totally unexpected; however, the magnitude of the change was startling. With a more deliberate attempt to select physiological variables by using the percent change form of the data, a regression model could be developed which could describe more adequately the salient physiological responses to prolonged physical work.

The regression analysis wherein percent of 3-minute physiological variables and PAQ scores were used selected General Fatigue to be the first variable. General Fatigue was followed by PRQ, PV_T, and $P\dot{V}_E$, the first three variables that were found in the regression analysis which used the percent of 3-minute physiological scores. Additionally, General Fatigue was minimally related to PRQ, PV_T, and $P\dot{V}_E$ (i.e., the percent of common variability was 2%, 10%, and 5% respectively, Table IV). Therefore, this analysis has shown that there remains some additional variability in ride duration that is related to feelings of General Fatigue that could provide useful information regarding factors which limit endurance performance.

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29. Borg, G. K Frysiogr Saellsk 31:105, 1961
30. Borg, G. J Rehab Med 2:92, 1970
31. Borg, G. Frontiers of Fitness. 1971, p 280
32. Noble, B.J. et al. Med Sci Sports 5:104, 1973

The somewhat limited success by which the PAQ subscales predicted ride duration could be interpreted as a developmental problem or a statement reflecting the subjective response to prolonged physical work. In the first report by Kinsman et al. (1), the leg fatigue items were in close association with the General Fatigue subscale. In a subsequent report following efforts to reduce these intercorrelations among the subscales, the relationship was again higher than would have been desired (2). In the present study, despite the substantial relationship to ride duration (r = 0.75), Leg Fatigue did significantly contribute to the predictability of ride duration and was the last variable taken into the regression equation. The small amount of added variability accounted for by the Leg Fatigue and Motivation subscales makes their usefulness in predicting ride duration questionable. However, in defense of the multifactorial approach it should be noted that changes in the form of the regression equation at different points in time could occur. For example, in another research situation where motivation was purposely increased and a different point in the ride was used for predicting a task duration, leg fatigue and motivation may prove to be more valuable predictors.

PERSONALITY AND RIDE DURATION

Individuals engaged in physical performance for relatively long periods of time rely on an on-going evaluation of the symptomatology associated with the work (28). This process permits readjustment of the work load level so that the individual can make changes in energy expenditure to permit successful completion of the task. An area of investigation related to this evaluation process concerns mechanisms involved in the processing of perceptual information and personality correlates. Until recently most of the theories that have dealt with these factors have had as their basis a process known as "blocking" (33). Blocking accounts for individual differences in the number of involuntary rest pauses (IRPs) that occur during motor tasks, such as rate of tapping. Subsequent to this work several personality theorists (10,11,34) found that performance and personality differences among individuals were related to the manner with which they process perceptual information. However, the degree to which the individual's perceptual reactance (Petrie's term) (11) can be modified by hereditary factors and environmental changes has not been specified. What has been shown with varying degrees of success is that performance differences in a variety of situations are related to physiologically based personality types.

Eysenck (10) has developed a two-dimensional classification of personality which he feels accounts for a substantial amount of variability

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33. Bills, A.G. Am J Psychol 43:230, 1931
34. Zuckerman, M. and K. Link. J Consult Clin Psychol 32:420, 1968

with regard to personality and performance differences among individuals. The two dimensions are extroversion-introversion (E-I) and neuroticism (N). The typical extrovert is "sociable, likes parties, has many friends, needs to have people to talk to, and does not like reading or studying by himself. He craves excitement, takes chances, often sticks his neck out, acts on the spur of the moment, and is generally an impulsive fellow." The typical introvert "is a quiet, retiring sort of person, introspective, fond of books rather than people; he is reserved and distant except to intimate friends. He tends to plan ahead, 'looks before he leaps,' and distrusts the impulse of the moment" (35).

High scores on neuroticism identify individuals that tend to be emotionally overresponsive and, in extreme cases, are prone to neurotic breakdown under stress. Low to moderate scores are indicative of more stable individuals (35).

When Eysenck began his work, the instrument that he used to classify individuals along the extroversion-introversion and neuroticism dimensions was a 48-item self-report questionnaire called the Maudsley Personality Inventory (MPI) (35). Reliability coefficients calculated for a variety of population samples were reported to range from 0.75 to 0.85 for extroversion-introversion and from 0.85 to 0.90 for neuroticism (35). Extensive validation data for the MPI were also included which strongly suggest that the MPI reflects extroversion-introversion and neuroticism tendencies in a manner comparable to clinical judgment. Another desirable characteristic of the MPI is the large amount of normative data available for different populations.

Research problems dealing with a variety of subjects, e.g., smoking (36), crime (37) have been approached using Eysenck's model. Of specific interest to the present work is persistence and the tolerance of pain. Lynn and Eysenck (7) hypothesized that because the extrovert tends to reach inhibition/satiation more rapidly than the introverted person, the extroverted person should tend to endure physical discomfort better. In this context inhibition/satiation is used to describe the degree to which the amount of somatosensory information perceived by the individual has been reduced. The results of their study indicated that heat tolerance is positively related to extroversion and negatively related to neuroticism. In another study by Costello and Eysenck (38) the same relationships were found for children who were asked to maintain a certain percent of their grip strength using a hand dynamometer. However, Levine et al. (39) failed to find a significant relationship between tolerance for shock and the E and N subscales after studying a group of students and a group of

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35. Knapp, R.R. Manual for the Maudsley Personality Inventory. 1962
36. Eysenck, H.J. Smoking, Health, and Personality. 1965
37. Eysenck, H.J. Crime and Personality. 1964
38. Costello, C.G. and H.J. Eysenck. Percept Mot Skills 12:169, 1961
39. Levine, F.M. et al. Percept Mot Skills 23:847, 1966

housewives. These authors attributed the differences between the studies to the procedural requirements in the latter study, wherein shock was intermittent and increased in stepwise fashion. Using an on/off presentation of shock as opposed to a constant level of discomfort during the heat stress may well have prevented the formation of inhibition/satiation. Based on these findings, the temporal/quantitative characteristics of the discomfort must be considered when evaluating tolerance for discomfort.

Another related concept, termed sensation seeking, has been developed by Zuckerman. Zuckerman et al. (40) hypothesized that individuals attempt to maintain "optimum levels of stimulation," and that certain individuals need "varied, novel, and complex sensations and experiences to maintain an optimum level of arousal." Stimuli that are repetitive cause a sensation seeker to become bored. The construct of sensation seeking has been suggested, with some supportive evidence, to be related to other personality traits, e.g., extroversion and field dependence (40), and autonomy (34). To categorize individuals along the sensation seeking dimension, Zuckerman (41) has developed the Sensation Seeking Scale (SSS). The scale in its present form contains a general sensation seeking scale (SSS-GEN) and four subscales: thrill and adventure seeking (SSS-TAS), experience seeking (SSS-ES), disinhibition (SSS-DIS), and boredom (SSS-BS). These subscales lack orthogonality due in part to item overlap that has yielded higher subscale intercorrelations than would be desired (40). Also, while some normative data and other test construction data have been and are being accumulated, further work with regard to these areas needs to be done.

The theoretical basis on which the SSS was founded is also based on the inhibition/satiation phenomenon. Presently, the amount of data required to delineate these relationships is not available. However, two studies describing GSR responses and sensation seeking have been reported. Zuckerman (41,42) noted that the GSR response on the first trial, i.e., the orienting response (OR) to visual and visual/auditory stimuli respectively, was significantly greater for sensation seekers. With repeated trials, rapid habituation (response decrement) of the GSR occurred for both groups, and in the latter study the sensation seekers' GSR responses dropped below those of non-sensation seekers. These findings suggest that the sensation seekers, a concept similar to "extroverts," as defined by Eysenck (10), strive for new and varied stimuli which are rapidly habituated when perceived.

It was on this basis of the individual's search for new stimuli that Garlington and Shimota (43) formulated their hypothesis of "change

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40. Zuckerman, M. et al. J Consult Clin Psychol 39:308, 1972
41. Zuckerman, M. Manual...for SSS. Univ Delaware, 1972, p 37
42. Zuckerman, M. Paper presented at Society for Psychological Research, St. Louis, 1971
43. Garlington, W.K. and H.E. Shimota. Psychol Rep 14:919, 1964

seeking." The concept of change seeking, according to these authors, involves stimuli from both internal and external sources. "Change seeking is an habitual, consistent pattern of behavior which acts to control the amount and kind of stimulus input a given organism receives." The theoretical basis is therefore founded in the behavioral patterns involving varied sensory-perceptual input. To determine those individuals that may be classified as being change seekers, Garlington and Shimota (43) used a 95-item self-report inventory called the Change Seekers Index (CSI). While normative data are almost non-existent, split-half and test-retest reliabilities reported by Garlington and Shimota (43) ranged from 0.89 to 0.92, except for one three month retest value that fell to 0.77. The authors stated that further work was in progress· however, no additional data have yet been found by this author. Despite such short-comings, the data available to support its theoretical construct suggest that the CSI merits further consideration.

One additional hypothesis that warrants consideration has been presented by Petrie (11). A thorough discussion of her work will not be presented because of the extensive testing requirements involved with her procedures, which precluded use of these procedures in the present study. When working with medical patients Petrie noted that certain individuals seemed to be less affected than others by similar maladies. From these observations she developed an approach for evaluating perceptual information processing by measuring the amount of kinesthetic "augmentation" or "reduction" experienced by individuals following repeated stimulation of specific kinesthetic senses. For example, using wooden blocks of different widths or small containers of varied weight, Petrie found that some individuals tended either to overestimate or underestimate the size or weight. Individuals categorized as augmenters (i.e., those that overestimated) appeared to do well in tasks involving sensory lack but did not endure physical discomfort as well as the reducers. The opposite was found to be true for reducers.

With recent emphasis on maintaining good health through physical fitness, research into the area of physical fitness and personality has increased (44). However, a typical approach has been to administer a personality questionnaire such as the Catell's Sixteen Personality Factor Questionnaire pre-and/or post-training and to describe the resultant changes. While this approach offers valuable information that can be used for guiding individuals in such programs, it does not offer explanations for individual preferences for varied types of work, nor does it account for some of the wide variability in persistence that cannot be explained solely on a physiological basis. The purpose of this section will be to attempt to account for some of the variability in persistence (riding a bicycle ergometer) that can be attributed to personality factors.

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44. Hammer, W.M. and J.H. Wilmore. J Sports Med 13:238, 1973

METHODS

Test Selection

As a measure of the extroversion-introversion and neuroticism dimensions of personality, the original MPI (Educational and Industrial Testing Service) was selected instead of the updated versions, the Eysenck Personality Inventory (45) or the Eysenck Personality Questionnaire (46), because of the large amounts of normative data available for American populations. This feature was viewed as an important consideration because of the relatively small number of subjects that were involved in this research project. The instructions presented in the MPI manual were followed when administering the questionnaire, and the responses of the subjects to the three-choice answers (i.e., yes, ?, and no) were recorded in the spaces provided on the test form.

Sensation seeking tendencies of individuals were measured with Zuckerman's Sensation Seeking Scale Form IV (Appendix E). The subjects were told to read the instructions on the front and to circle their choices for each item.

Evaluation of the need for change was determined by the Change Seekers Index that was re-typed from the literature source (43). The volunteers were told to read the instructions and then indicate their answers, true or false, as the items applied to them most of the time. Answers were recorded on separate answer forms.

Procedure

When participants arrived for their first test session, they were seated individually in a classroom adjacent to the human performance laboratory. They were told to read the instructions carefully, and if they had any questions regarding the tests, to ask them before beginning to answer each inventory. No time restrictions were placed on the tests. The MPI was scored with the hand-held keys included with the questionnaires. The SSS and CSI were scored in accordance with the instructions by the authors (43).

Statistics

Pearson product-moment correlations were computed by computer routines contained in the Statistical-Package-for-the-Social-Sciences (SPSS) system at the University of Colorado. The 0.05 level was selected for significance. When missing data were encountered, the

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45. Eysenck, H.J. and S.B.G. Eysenck. The Manual of the Eysenck Personality Inventory. 1969
46. Eysenck, H.J. and S.B.G. Eysenck. The Manual of the Eysenck Personality Questionnaire. 1975

SPSS pair-wise deletion option was used. This occurred when one of the subjects did not complete a page on the SSS, and because the subject's questionnaire was not scored until a later time, these data were not obtained. Additionally, as noted earlier, the work load for subject number 5 during his 65% $M\dot{V}_{O_2}$ ride was too high; hence, the data for his 65% ride could not be used. Therefore, the numbers of subjects for the 65% and 85% rides were 12 and 13 respectively for the SSS computations. For the CSI and MPI the numbers were 13 and 14 respectively. The order of the personality tests was intended to be completely counterbalanced; however, because three subjects dropped out of the study and one failed to appear, complete counterbalancing was not achieved.

RESULTS

Presented in Table VI are the means and standard deviations ($\bar{X}$, $\pm$ SD) for each of the personality measures and the two ride durations. Included with these data are the American college norms reported for each of the scales. All of the means and standard deviations compare favorably with those reported for the college norms except for E-I, which indicated that the present group tended to be slightly more introverted (30th percentile, stanine = 4).

Pearson product-moment correlations measuring relationships among the personality measures are presented in Table VII. MPI E-I was found to be negatively related to the MPI N scale and positively related to the SSS-DIS scale. According to Knapp (35), MPI E-I x MPI N subscale correlations were about the magnitude of -0.15 except for populations that include a large number of high N scores. Since the means and standard deviations on the N subscale for subjects in this study noted above do not reflect such a distribution of scores, these data do not substantiate such an interpretation. Significant E-I x SSS-DIS correlations have been reported previously (40), but only for female subjects. However, a similar finding for male subjects would be in keeping with the concepts of these personality dimensions.

Regarding the MPI N subscale, the only significant relationship found other than the one noted above was the MPI N x CSI correlation. An earlier study that supports this relationship was performed by Garlington and Shimota (43) wherein the CSI was able to select 30 institutionalized neurotics from among a larger group of 90 patients. The CSI was also related to the SSS-GEN, SSS-ES, and SSS-BS subscales. Zuckerman et al. (40) has reported that "Correlations of the SSS above 0.60 have been found only with other types of similar scales such as Garlington and Shimota's (43) Change Seekers Index...."

With regard to the remaining ten correlations among the SSS subscales, five were significant, with three additional relationships having $P < 0.06$. As mentioned previously, the SSS subscales have been reported to be significantly related. This is clearly verified by the present study.

Also included in Table VII is the correlation for each subscale with the 65% and 85% ride times. The pattern of the correlations for the two rides are strikingly similar. Only one subscale, the SSS-DIS, was significantly related to length of ride, but surprisingly, the relationships were both negative. This finding indicates that persons who rode the longest were those who were the most inhibited and who tended to be introverted.

COMMENT

Based on the results of this study, several points merit further comment. First, with the exception of the slightly lower score on the MPI E-I subscale, all means and standard deviations compare favorably with normative data. Concerning the MPI E-I x N relationship, Cohen and Horn (47) and Horn and Cohen (48) also found a significant relationship between these two subscales for seven samples of undergraduate students from the University of Texas (N = 1,406) which indicates that for certain samples, the independence reported by Eysenck for E-I and N may be overstated. Therefore, the significant relationship between MPI E-I and N subscales that has been dismissed by Eysenck (49) attributable to sampling remains to be explained.

The CSI was significantly related to the MPI N and SSS GEN, ES, and BS subscales in this study. While no reports of tests for relationships between MPI N and SSS subscales could be retrieved, a significant positive CSI x GEN-GEN relationship was reported by Farley (50). Because of the recent development of the SSS subscales, specific CSI x SSS subscale intercorrelations have not been previously reported. However, such relationships would not be unexpected from the somewhat high intercorrelations among the SSS subscales that were noted by Zuckerman et al. (40) and confirmed by the present study.

The SSS-DIS was the only personality measure significantly related to ride duration. Contrary to expectations, the pattern of this correlation was negative. Another noteworthy finding related to this point is the correlation of ride duration with the CSI; this correlation narrowly missed significance and was also negative. This was also true for the Ride Duration x MPI E correlations. These findings, in addition to the highly significant relationship noted between SSS-DIS x MPI E-I, seem to indicate that a process opposite to the original inhibition/satiation hypothesis appears to be operating for this work task.

Interpretation of such results within the framework of the inhibition/satiation model would appear to be unsatisfactory except for work

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47. Cohen, D.B. and J.M. Horn. J Abnorm Psychol 83:304, 1974
48. Horn, J.M. and D.B. Cohen. J Abnorm Psychol 83:311, 1974
49. Eysenck, H.J. J Abnorm Psychol 83:308, 1974
50. Farley, F.H. J Consult Clin Psychol 37:394, 1971

that was accomplished in three previous investigations. First, Petrie (11) reported in her work that individual differences in the effectiveness of audioanalgesia for dental patients could be explained on the basis of the perceptual reactance experienced by the "augmenters" and "reducers." The augmenters (a term describing those individuals that subjectively exaggerate any sensory information perceived, comparable to Zuckerman's non-sensation seeker and Eysenck's introvert) appeared to experience a greater pain reducing effect from white noise presented through earphones than the reducers. Petrie interpreted this finding to mean that the sensory bombardment with a secondary stimulus provided a sensory overload for the augmenters because of their tendency to enlarge the stimulus input, while the reducers tended to attenuate the effect of the secondary stimulus. A second study performed by Shigehisa and Symons (51) investigated a phenomenon which, according to these authors, exists in Russian literature as the "law of inversion." These investigators found that the threshold of a primary stimulus (sound) was reduced as the intensity of a heteromodal stimulus (i.e., a secondary stimulus of light) increased for extroverted subjects. However, for introverted subjects the effect was the same until the intensities of light reached the highest levels, and then their thresholds for sound significantly increased. In both studies the law of inversion worked best for those individuals who normally tend to enlarge subjectively the sensory information that is perceived. Finally, a study performed by Morgan and Costill (52) provides some collaborative evidence for these findings. The authors mailed the Eysenck Personality Inventory to eleven marathon runners and asked them to complete the questionnaire. When the results of nine respondents were compared to those of other previously tested groups of athletes, the data showed that these runners were significantly more introverted. Comparisons between means of other college samples (12.08) and the runners (9.55) were not made because the authors questioned the possible effects of sampling. While the testing procedures utilized by Morgan and Costill are not recommended by Eysenck (49), the results are nonetheless interesting.

To evaluate personality factors that affect performance, it is apparent that the characteristics of the sensory environments, internal and external, must be specified. Presentation characteristics, such as duration and rate noted by Levine et al. (39), and intensity as noted by Shigehisa and Symons (51), are needed. Unfortunately, for this study such information is unavailable, and to demonstrate the law of inversion effects based on two work loads would be inappropriate. Work performance at three or more load levels which vary from light to heavy could provide such information.

One further point which should be noted (but unfortunately was not properly evaluated in this study) concerns prior histories of endurance

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51. Shigehisa, T. and J.R. Symons. Br J Psychol 64:205, 1973
52. Morgan, W.P. and D.L. Costill. J Sports Med 12:42, 1972

training of the subjects. Despite the equating of work load levels using the percent of $\dot{V}_{O_2}$ Max levels, it was observed that several of the subjects who rode the longest reported prior histories of endurance training through high school and college sports (e.g., soccer, tennis, cross country skiing, and track). However, the validation of such evidence would also be incongruous with the model which hypothesizes that the more inhibited, introverted individual should tend to seek out activities that do not require endurance of physical discomfort for prolonged periods of time.

CONCLUSIONS

It can be concluded that the investigation of the areas within the model originally proposed met with limited success. The loss of substantial amounts of EMG data precluded further interpretation of these results. Several of the specific variables that were hypothesized to be related to each of the PAQ subscales did show significant relationships. Unfortunately, several additional variables that were not hypothesized to be related to the Leg Fatigue subscale were also found to be significant. Since the physiological response to physical work is not usually isolated to a single system, the extent to which this general effect served to elevate the magnitude of the relationships between the Leg Fatigue subscale and these other physiological variables cannot be presently determined. However, the significant relationships found for those physiological variables that were specifically hypothesized to be related to each subscale do support the usefulness of the multidimensional approach to evaluating the subjective experience of fatigue.

The personality model that was based on the inhibition/satiation mechanism and proposed that athletes tended to be less inhibited, extroverted, and would perform best in tasks requiring tolerance of discomfort, was not supported. In fact, a reverse process appears to be operating, and this finding was supported by another study (52). A possible answer may be found in the prior history of each individual which includes a knowledge of his preference for selected work tasks.

It is tempting to speculate that since subjects were equated for work loads, any differences in ride duration should be attributable to tolerance for discomfort. However, the fact that the longer riders appeared to enter some type of steady state while the short riders did not does not support such an interpretation.

RECOMMENDATIONS

It should be determined the extent to which psychosocial factors (i.e., group versus individual efforts) and the physical demands of the work task (i.e., intensity, duration, and rate) serve to affect the work task differentially. Such information may account for additional individual variability and preference for physical work.

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LEGENDS OF FIGURES

APPENDIX A

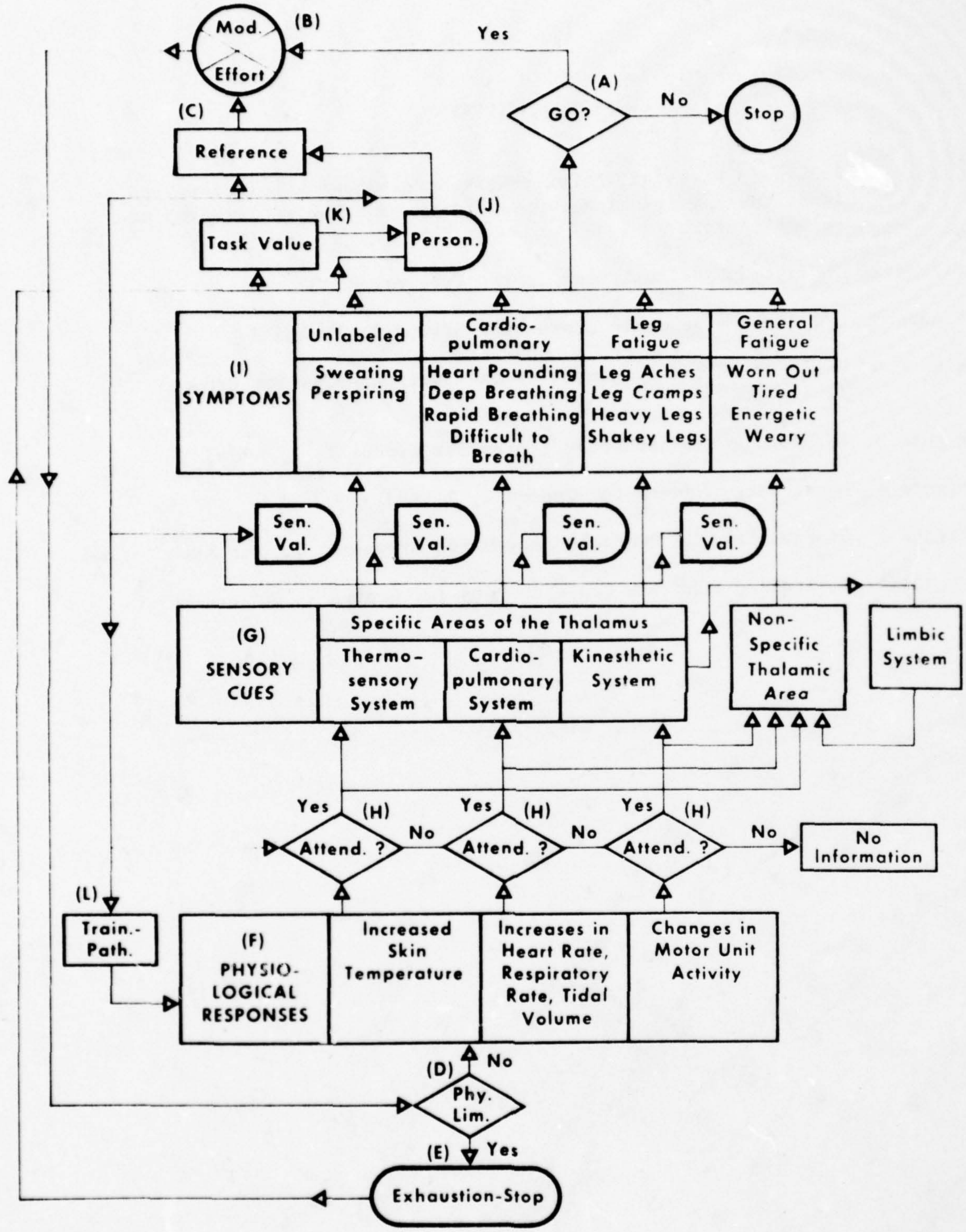

Figure 1. **Prolonged Physical Work Model Showing Relationships among the Physiological, Personality, and Subjective Symptomatology Factors.**

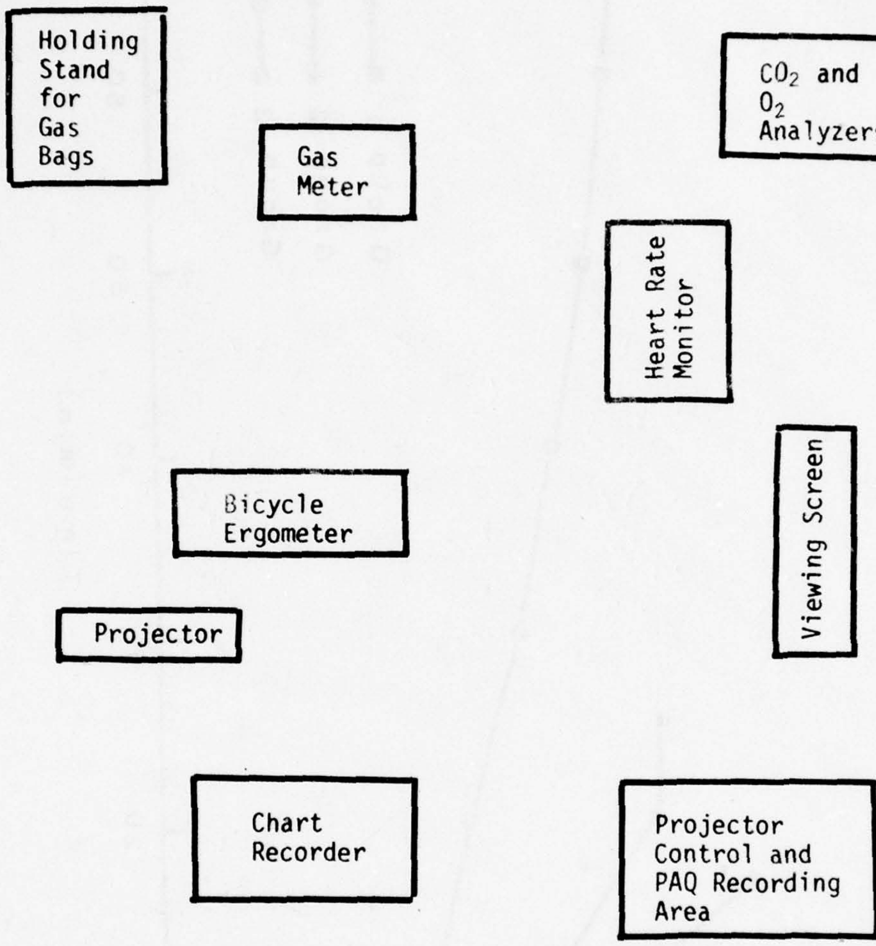

Figure 2. Arrangement of Equipment in the Test Area

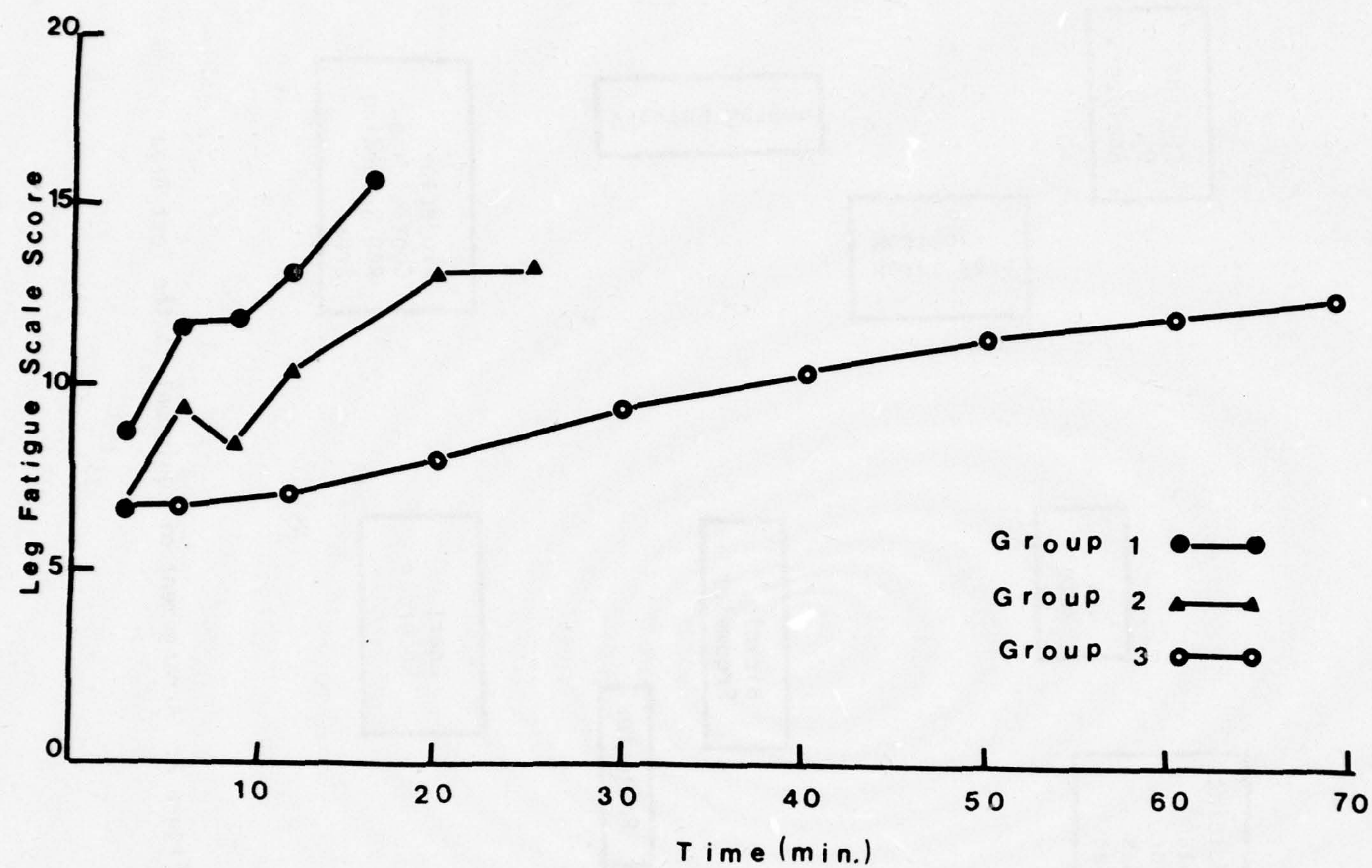

FIGURE 3. LEG FATIGUE SUBSCALE SCORES FOR GROUPS 1, 2, AND 3.

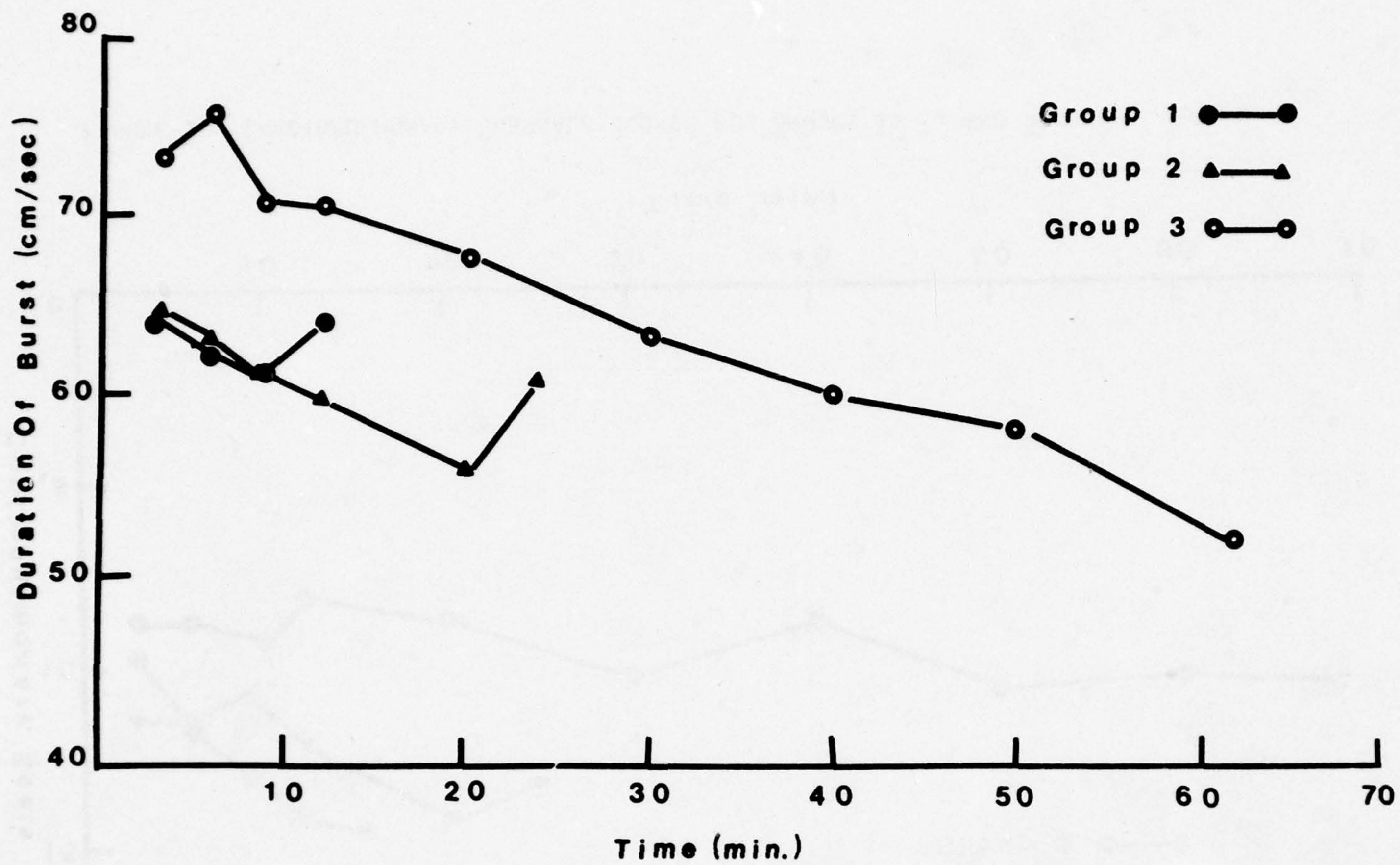

FIGURE 4. DURATION OF THE EMG BURST OF THE GASTROCNEMIUS FOR GROUPS 1, 2, AND 3.

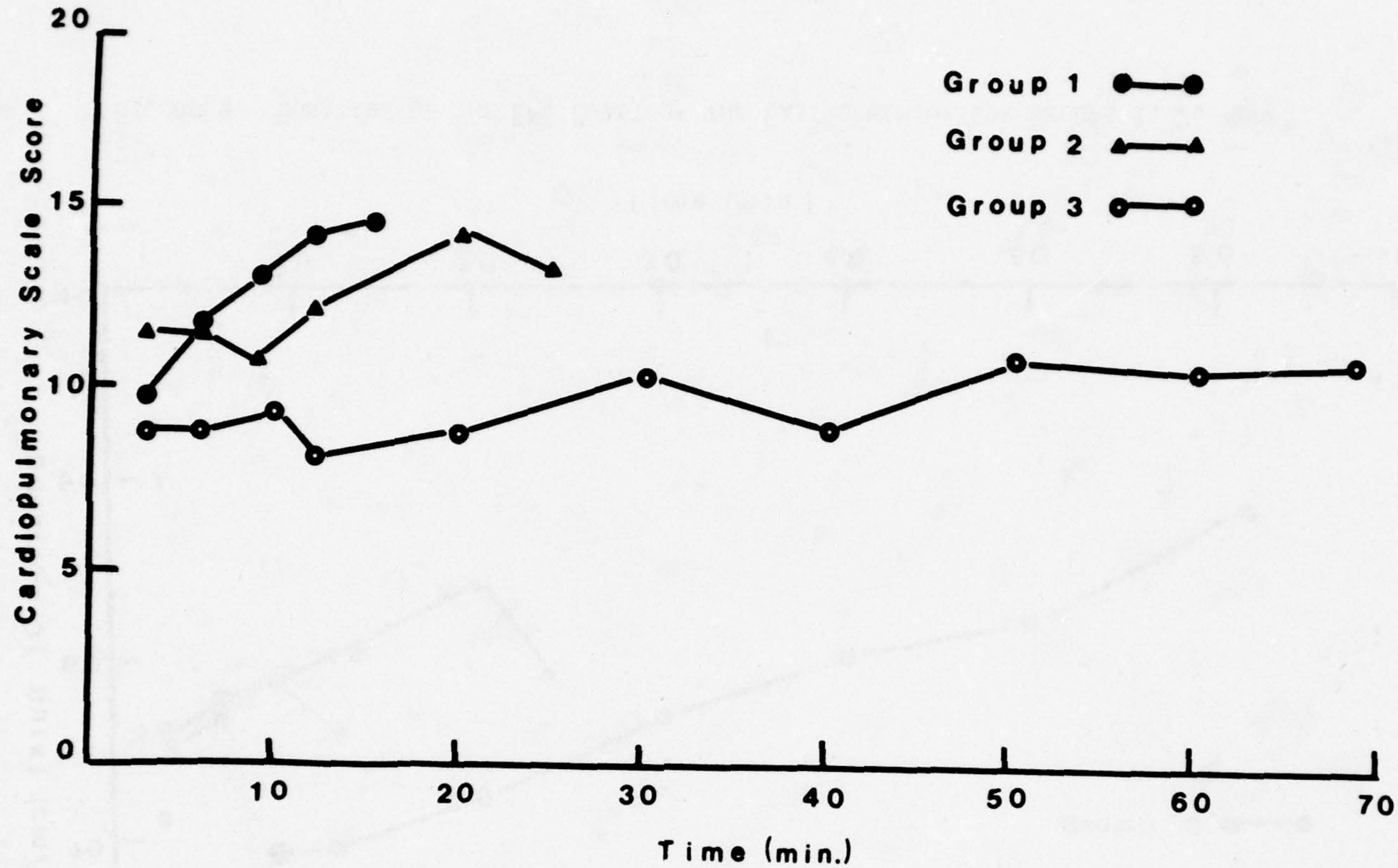

FIGURE 5. CARDIOPULMONARY SUBSCALE SCORES FOR GROUPS 1, 2, AND 3.

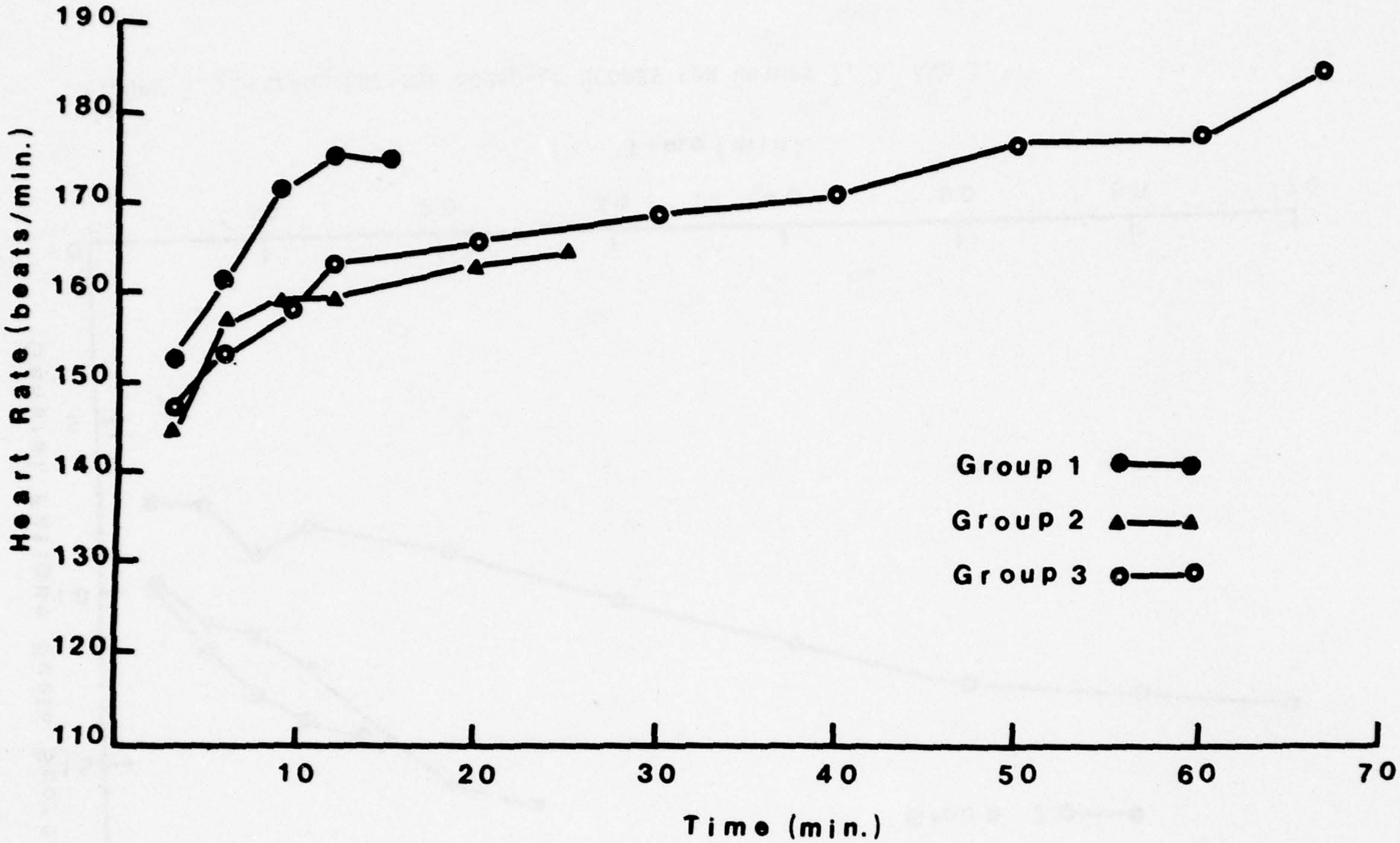

FIGURE 6. HEART RATE CHANGES FOR GROUPS 1, 2, AND 3.

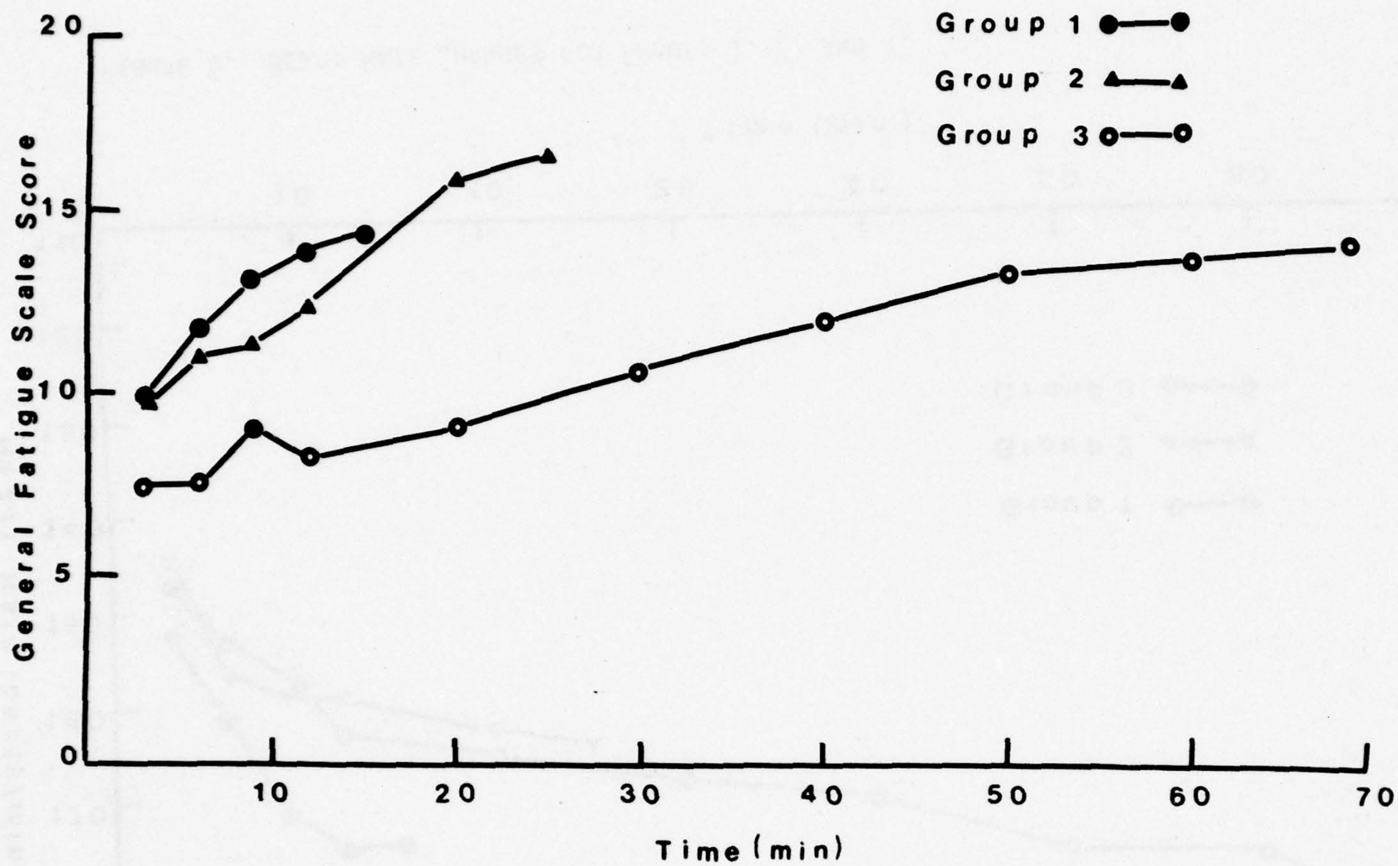

FIGURE 7. GENERAL FATIGUE SUBSCALE SCORES FOR GROUPS 1, 2, AND 3.

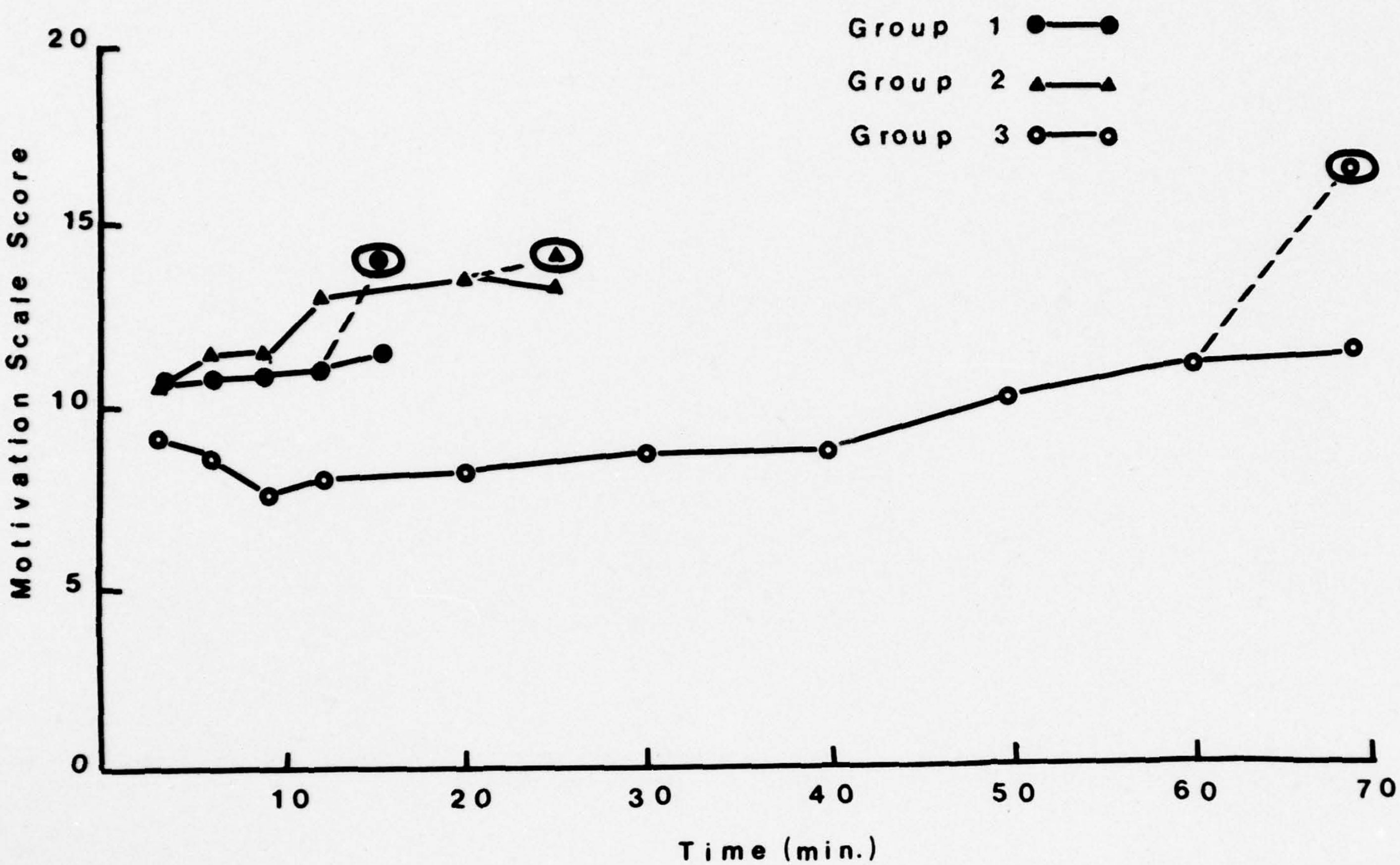

FIGURE 3. MOTIVATION SUBSCALE SCORE CHANGES FOR GROUPS 1, 2, AND 3.

TITLES OF TABLES

APPENDIX B

TABLE I

ANTHROPOMORPHIC CHARACTERISTICS OF THE SUBJECTS (N = 14)

	Age (years)	Weight (kg)	$\dot{V}_{O_2}$ Max (ml/kg/min)
Mean	21.71	70.59	52.65
SD	2.2	7.92	9.71
Range	18-27	56.8-85.9	38.52-70.49

TABLE II

RIDE SCHEDULE

Subjects	Session 1	Session 2	Session 3	Session 4
1-9	Personality Tests PAQ Familiarization Ride (three 5-minute submaximal rides)	Max $\dot{V}_{O_2}$ Ride (no PAQ)	Ride 1	Ride 2
10-14	Personality Tests PAQ Familiarization as part of determination of V Max	Ride 1	Ride 2	

PAQ = Physical Activity Questionnaire

$\dot{V}_{O_2}$ Max = Maximum Oxygen Uptake

TABLE III

SUMMARY OF RELATED t-TESTS:
3-MINUTE TO END-OF-RIDE COMPARISONS

Variable	Group I t	Group II t	Group III t
Leg Fatigue	9.89**	2.89*	4.35**
Cardiopulmonary	3.12*	1.58	2.36*
General Fatigue	3.58*	7.89**	5.48**
Motivation	1.00	1.51	1.65
Duration Gastrocnemius	.04	6.94*	3.58*
Heart Rate	5.93**	7.65**	7.28**

* P <0.05
** P <0.01

TABLE IV

CORRELATIONS BETWEEN PAQ SUBSCALES AND PHYSIOLOGICAL MEASURES

	Leg Fatigue	General Fatigue	Cardio-pulmonary	Motivation
Duration Vastus Lateralis	-.30*	-.34*	-.27*	-.26*
Duration Gastrocnemius	-.45*	-.31*	-.05	.27*
Amplitude Vastus Lateralis	-.08	-.28*	-.02	.14
Amplitude Gastrocnemius	.00	-.10	-.16	-.37*
$\dot{V}_E$ BTPS	.05	.09	.01	-.22*
RQ	-.15	-.27*	.10	.06
$\dot{V}_{O_2}$	.04	.13	.06	-.05
CO	.05	.14	.06	-.05
SV	-.24*	-.07	-.10	-.08
Energy Expenditure	.04	.12	.07	-.05
$\dot{V}_{O_2}$/ml/kg	-.04	.08	-.12	-.14
HR	.49*	.35*	.27*	.06
RR	.13	.16	-.02	-.04
V_T	-.16	-.12	.05	-.05
$P\dot{V}_O$ Max	.22*	.14	.12	.01
$P\dot{V}_E$ BTPS	.36*	.17	.17	-.04
PRQ	-.20	-.23*	-.18	-.08

-continued on page 46

TABLE IV (Continued)

CORRELATIONS BETWEEN PAQ SUBSCALES AND PHYSIOLOGICAL MEASURES

	Leg Fatigue	General Fatigue	Cardio-pulmonary	Motivation
PCO	.34*	.21*	.21*	.11
PSV	-.19	-.27*	.05	.12
$P\dot{V}O_2$	.34*	.21*	.21*	.13
PHR	.39*	.37*	.09	-.03
PRR	.37*	.28*	.19	.18
PV_T	-.22*	-.32*	-.21*	-.28*

*P <.05

TABLE V

RESULTS OF THE MULTIPLE STEPWISE REGRESSION ANALYSIS

Step	Independent Variable	Simple r	Multiple R	R^2	Overall F	Significance
			Raw Physiological Data			
1	RR	-.44	.44	.19	2.11	>.05
2	HR	-.39	.52	.27	1.50	>.05
3	RQ	-.08	.53	.29	.93	>.05
4	$\dot{V}O_2$	.03	.55	.30	.64	>.05
			Percent of 3-minute Physiological Data			
1	PRQ	.67	.67	.45	7.39	<.05
2	PV_T	.47	.83	.69	9.00	<.01
3	$P\dot{V}_E$	-.27	.90	.81	9.81	<.01
4	PSV	-.16	.94	.89	11.93	<.01
			PAQ Subscales			
1	Gen Fat	-.77	.77	.59	13.12	<.01
2	Cardio	-.76	.80	.64	7.16	<.05
3	Motiv	-.48	.81	.66	4.44	<.05
4	Leg Fat	-.75	.81	.66	2.95	>.05
			Percent of 3-minute Physiological Data and PAQ Subscales			
1	Gen Fat	-.77	.77	.59	13.13	<.01
2	PRQ	.67	.88	.77	13.43	<.01
3	PV_T	.48	.98	.96	49.58	<.001
4	$P\dot{V}_E$	-.27	.99	.99	131.55	<.001

TABLE VI

MEANS AND STANDARD DEVIATIONS OF
PERSONALITY MEASURES AND RIDE TIMES

Variable	$\bar{X}$	SD
MPI E-I	23.77	7.55
(College Norm)	(28.73)	(8.18)
MPI N	20.00	10.93
(College Norm)	(20.66)	(10.65)
CSI	52.61	7.20
(College Norm)	(49.06)	(12.35)
SSS-GEN	15.00	3.02
(College Norm)	(12.8)	(3.7)
(College Norm)	(13.4)	(3.6)
SSS-TAS	12.06	1.24
(College Norm)	(10.6)	(2.7)
(College Norm)	(11.1)	(2.6)
SSS-ES	10.67	3.77
(College Norm)	(9.2)	(3.9)
(College Norm)	(9.6)	(3.9)
SSS-DIS	4.83	3.24
(College Norm)	(6.4)	(3.2)
(College Norm)	(6.7)	(3.3)
SSS-BS	7.83	2.76
(College Norm)	(7.7)	(3.2)
(College Norm)	(7.8)	(3.1)

TABLE VII

CORRELATION MATRIX FOR THE SUBSCALES OF THE MPI
AND SSS, THE CSI, AND THE TWO PERFORMANCE RIDES

Variable	1	2	3	4	5	6	7	8	9	10
1. MPI E-I	-	-.56*	-.38	-.26	.33	.14	.71**	.04	-.33	-.30
2. MPI N		-	.72**	.45	-.26	.23	-.20	.19	-.22	-.30
3. CSI			-	.58*	-.14	.50*	.16	.51*	-.40	-.39
4. SSS-GEN				-	.46	.80	.24	.71**	-.27	-.06
5. SSS-TAS					-	.59*	.36	.62*	.06	.04
6. SSS-ES						-	.46	.74**	-.29	-.36
7. SSS-DIS							-	.46	-.74**	-.51*
8. SSS-BS								-	-.09	-.18
9. 65% Ride Duration									-	.62*
10. 85% Ride Duration										-

*P <.05
**P <.01

INFORMED CONSENT FOR BICYCLE ERGOMETER TEST

1. Explanation of the bicycle ergometer and personality tests. During the course of this study you will be asked to perform four rides on a bicycle ergometer and to report on the fatigue you experience. Additionally, you will be asked to complete three personality questionnaires. During the first session the three personality questionnaires and two short rides to allow you to become familiar with the procedures will be accomplished. In session 2 the ride will begin at a submaximal heart rate level and advance in stages to determine your maximal oxygen uptake value that will be used to establish your work load settings that will be used in sessions 3 and 4. In sessions 3 and 4 you will be asked to perform rides at two different work load settings and to report on the fatigue you experience. You will not be encouraged to push yourself beyond safe levels of exercise and you may be asked to stop because of physiological signs of fatigue.

2. Risks and discomfort. There exists the possibility of certain changes occurring during exercise. They include abnormal blood pressure, fainting, disorders of heart beat, and in very rare instances heart attacks. However, these possibilities will be minimized by a preliminary medical examination and by continuous monitoring during the rides. Emergency equipment and trained personnel are available to deal with unusual situations which may occur.

3. Benefits to be expected. The results obtained from the exercise tests may be useful in providing you with useful information regarding your physiological capacities. Additionally, the research objectives of the tests may provide you with useful information concerning factors affecting the performance of various tasks.

4. Inquiries. Any questions regarding the procedures used during the exercise tests will be welcomed at any time and all questions will be answered fully at the completion of the study.

5. Freedom of consent. Permission to perform these tests is voluntary and you are free to deny consent if you so desire.

I have read this form, and I understand the test procedures that I will perform and consent to participate in these tests.

________________ Date

________________ Signature of Student

________________ Witness

APPENDIX C

PHYSICAL ACTIVITY QUESTIONNAIRE

LEG FATIGUE

Leg Twitching

1	2	3	4	5
Severe	Considerable	Moderate	Slight	Not at All

Heavy Legs

1	2	3	4	5
Not at All	Slightly	Moderately	Very	Extremely

Leg Cramps

1	2	3	4	5
Severe	Considerable	Moderate	Slight	No

Aching Leg Muscles

1	2	3	4	5
Not at All	Slightly	Moderately	Considerably	Severely

GENERAL FATIGUE

Tired

1	2	3	4	5
Extremely	Very	Moderately	Slightly	Not at All

Worn Out

1	2	3	4	5
Not at All	Slightly	Moderately	Considerably	Extremely

Out of Energy

1	2	3	4	5
Not at All	Slightly	Moderately	Considerably	Extremely

Exhausted

1	2	3	4	5
Extremely	Considerably	Moderately	Slightly	Not at All

APPENDIX D

CARDIO-RESPIRATORY

Hard to Breathe

1	2	3	4	5
Extremely	Considerably	Moderately	Slightly	Not at All

Rapid Breathing

1	2	3	4	5
Very Rapid	Rapid	Moderately Rapid	Slightly Rapid	No

Deep Breathing

1	2	3	4	5
Very Deep	Deep	Moderately	Slightly	No

Heart Pounding

1	2	3	4	5
Severe	Considerable	Moderate	Slight	Not at All

MOTIVATION

Want to Perform Well

1	2	3	4	5
Indifferent	Slightly	Moderately	Considerably	Very Much

Willing to Endure Discomfort

1	2	3	4	5
Extremely	Very	Moderately	Slightly	Not at All

Determined to Ride for a Long Time

1	2	3	4	5
Not at All	Slightly	Moderately	Very	Extremely

Drive to Outperform Other Subjects

1	2	3	4	5
Indifferent	Slight	Moderate	Much	Very Much

GLOSSARY

$\dot{V}_{O_2}$ Max	The maximum level for oxygen transportation (also M $\dot{V}_{O_2}$)
$\dot{V}_E$ BTPS	Expiratory gas volume/minute corrected to body temperature and pressure, saturated with water vapor
RR	Number of breaths/min
V_T	Tidal volume (volume of gas moved during any respiratory cycle)
RQ	Respiratory exchange ratio (CO_2/O_2)
$\dot{V}_{O_2}$	Volume of oxygen/min(oxygen uptake/min)
CO	Cardiac output (estimated)
SV	Stroke volume (volume of blood expelled from the heart beat)
EMG	Electromyogram (recording of the electrical activity of the muscles)
$AgNO_3$	Silver nitrate
ECG	Electrocardiogram (measurement of the electrical activity of the heart)
P(XX)	The P preceding any of the above cardiovascular and pulmonary symbols indicates that the value represents a percent of its 3-minute level. The only exception $P\dot{V}_{O_2}$ which is based on each person's $\dot{V}_{O_2}$ MAX.
GSR	Galvanic skin response (measurement of the resistance changes of the skin)
OR	Orienting response (response to a stimulus during the first trial)
HR	Heart rate in beats per minute

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